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While the technology and concepts defining warfare have continuously and rapidly transformed, the primary actor in warfare – the human – has remained largely unchanged. Soldiers today may be physically larger, more thoroughly trained, and better equipped than their historical counterparts, but their capability and performance abilities remain very similar. The limitations of human performance, however, may change over the next 30 years, as advances in biotechnology and human performance likely will expand the boundaries of what is possible for the human to achieve. We may see Soldiers — not just their equipment — with superior vision, enhanced cognitive abilities, disease/virus resistance, and increased strength, speed, agility, and endurance. As a result, these advances could provide the Soldier with an edge to survive and thrive on the hyperactive, constantly-changing, and increasingly lethal Multi-Domain Battlespace.

In addition to potentially changing the individual physiology and abilities of the future Soldier, there are many technological innovations on the horizon that will impact human performance. The convergence of these technologies – artificial intelligence (AI), robotics, augmented reality, brain-machine interface, nanotechnologies, and biological and medical improvements to the human – is referred to as *bio convergence*. Soldiers of the future will have enhanced capabilities due to technologies that will be installed, instilled, and augmented. This convergence will also make the Army come to terms on what kinds of bio-converged technologies will be accepted in new recruits.

To explore the effect of the technologies and concepts that will impact the Soldier of 2035-2050, the United States Army Training and Doctrine Command (TRADOC) co-hosted the Mad Scientist: Bio-Convergence and Soldier 2050 Conference with SRI International on 8 – 9 March 2018 in Menlo Park, California. The conference explored bio convergence, what the Army Soldier of 2050 will look like, and how they will interact and integrate with their equipment. In support of the event, Mad Scientists published 16 submissions from our “Call for Ideas” writing contest, ranging from traditional white papers on bio convergence topics to “Letters from the Frontline” postulating Soldiers’ messages home from the frontline in 2035-2050. Conference attendees included representatives from private industry, academia, and a host of government and military organizations including the Office of the Secretary of Defense, Army Staff, Defense Threat Reduction Agency, Research, Development, and Engineering Command, Army Research Lab, Department of Homeland Security and other Intelligence Community elements. Keynote speakers discussed a number of topics ranging from ethics in human augmentation and enhancement to technology and medical rapid prototyping. Additionally, several hundred other global participants viewed the conference via live streaming on the Internet.

Many viewers and attendees also participated in a bio convergence technologies wargame that was coordinated with the Deputy Assistant Secretary of the Army for Research and Technology (DASA R&T) and the University of Southern California’s Institute for Creative Technologies. The game allowed participants to showcase new technology and concept ideas in bio convergence as well as to comment on and invest

in other's ideas. All of this input was mined for useful ideas that will aid in understanding the capabilities and vulnerabilities of the future biologically/technologically-augmented Soldier.

The conference generated the following key findings:

- The democratization of technologies and global proliferation of information has expanded the arena of high-end threat capabilities beyond nation states, and now includes non-state actors and super-empowered individuals.
- Advances in synthetic biology likely will enhance future Soldier performance – speed, strength, endurance, and resilience – but will bring with it vulnerabilities, such as genomic targeting, that can be exploited by an adversary and/or potentially harm the individual undergoing the enhancement.
- Designer viruses and diseases will be highly volatile, mutative, and extremely personalized, potentially challenging an already stressed Army medical response system and its countermeasures. Synthetic biology provides an opportunity for the Army to accelerate the development of treatments and vaccines.
- The dramatic shift in the funding, driving, and demand signals of innovation from the U.S. Government to the commercial sector leads to a critical need for agile prototyping and experimentation in the military – focusing on niche areas of interest to the government.
- The advent of new biotechnologies will give rise to moral, regulatory, and legal challenges for the Army of the Future, its business practices, recruiting requirements, Soldier standards, and structure.

The Wide Range of Competition

The democratization of technologies and global proliferation of information has expanded the arena of high-end threat capabilities beyond nation-states and now includes non-state actors and super-empowered individuals.

The broad advancement of biotechnologies will provide wide access to dangerous and powerful bioweapons and human enhancement. The low cost and low expertise entry point into gene editing, human performance enhancement, and bioweapon production has spurred a string of new explorations into this arena by countries with large defense budgets – i.e., China –, non-state criminal and terrorist organizations – i.e., ISIS –, and even super empowered individuals willing to subject their bodies to experimental and risky treatments.

China has invested billions of dollars into biotechnology – including in several U.S. biotechnology firms – and plans on focusing on their own bio revolution. Gene editing is one of the areas where China has sought to leapfrog the United States through ambitious Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) projects, editing the genes of 86 individuals. The United States just now is approaching human trials. Additionally, Elsa Kania, an expert on Chinese emerging technology from the Center for the New American Security (CNAS) noted that China is focusing on building its own innovation base rather than focusing on intellectual property theft and technology transfers.

Non-state actors – mainly terrorist organizations – have focused more on weaponizing bio technology. A personal laptop belonging to ISIS that was captured in Syria, was found to contain lessons on making bubonic plague bombs and the employment of various weapons of mass destruction (WMDs). The possession of this dangerous information by the most notorious terrorist organization across the globe is a testament to the worldwide proliferation of information. This challenge of weaponized biotechnology is exacerbated by the relative ease of obtaining material to carry out such attacks.

There is a growing community of individual biohackers and “do it yourselfers,” (DIYers) pushing the boundaries of DNA editing, implants, embedded technologies (embeds), and unapproved chemical and biological injections. One of the most prominent biohackers, Josiah Zayner, a former NASA employee with a biophysics PhD, livestreamed his self-injection of CRISPR and has even started a company selling DIY CRISPR kits ranging from several hundred to over 1000 dollars, effectively enabling biohackers to cheaply change their physiology, alter their appearance, and go beyond

human biological norms.^{1,2} None of these treatments are approved by regulatory agencies and DIYers run the serious risk of harming themselves or unleashing destructive and disruptive biological agents upon an unwitting population.

Benefits and Vulnerabilities of Soldier Enhancement

Advances in synthetic biology likely will enhance future Soldier performance – speed, strength, endurance, and resilience – but will bring with it vulnerabilities, such as genomic targeting, that can be exploited by an adversary and/or potentially harm the individual undergoing the enhancement.

Emerging synthetic biology tools – e.g., CRISPR, Talon, and ZFN – present an opportunity to engineer Soldiers' DNA and enhance their abilities. Bioengineering is becoming easier and cheaper as a bevy of developments are reducing biotechnology transaction costs in gene reading, writing, and editing.³ Due to the ever-increasing speed and lethality of the future battlefield, combatants will need cognitive and physical enhancement to survive and thrive.

Cognitive enhancement could make Soldiers more lethal, more decisive, and perhaps more resilient. Using neurofeedback, a process that allows a user to see their brain activity in real time, one can identify ideal brain states, and use them to enhance an individual's mental performance. Through the mapping and presentation of identified expert brains, novices can rapidly improve their acuity after just a few training sessions.⁴ Further, there are studies being conducted that explore the possibility of directly emulating those expert brain states with non-invasive EEG caps that could improve performance almost immediately.⁵ Dr. Amy Kruse, the Chief Scientific Officer at the Platypus Institute, referred to this phenomenon as “sitting on a gold mine of brains.”

There is also the potential to change and improve Soldier's physical attributes. Scientists can develop drugs, specific dietary plans, and potentially use genetic editing to improve speed, strength, agility, and endurance. In order to fully leverage the capability of human performance enhancement, Andrew Herr, CEO of Helicase and an Adjunct Fellow at CNAS, suggested that human performance R&D be moved out of the medical field and become its own research area due to its differing objectives and the convergence between varying technologies. Soldiers, Airmen, Marines, and Sailors are already trying to enhance themselves with commercial products – often containing

¹ <https://www.newscientist.com/article/mg23631520-100-biohackers-are-using-crispr-on-their-dna-and-we-cant-stop-it/>

² <https://gizmodo.com/genetically-engineering-yourself-sounds-like-a-horrible-1820189351>

³ Ahmad, Zarah and Stephanie Larson, “The DNA Utility in Military Environments,” slide 5, presented at Mad Scientist Bio-Convergence and the Soldier 2050 Conference, 8 March 2018.

⁴ Kruse, Amy, “Human 2.0 Upgrading Human Performance,” Slide 12, presented at Mad Scientist Bio-Convergence and the Soldier 2050 Conference, 8 March 2018

⁵ <https://www.frontiersin.org/articles/10.3389/fnhum.2016.00034/full>

unknown or unsafe ingredients – so it is incumbent on the U.S. military to, at the very least, help those who want to improve.

However, a host of new vulnerabilities, at the genetic level, accompany this revolutionary leap in human evolution. If one can map the human genome and more thoroughly scan and understand the brain, they can target genomes and brains in the same ways. Soldiers could become incredibly vulnerable at the genomic level, forcing the Army to not only protect Soldiers using body armor and armored vehicles, but also protect their identities, genomes, and physiologies.

Adversaries will exploit all biological enhancements to gain competitive advantage over U.S. forces. Targeted genome editing technology such as CRISPR will enable adversarial threats to employ super-empowered Soldiers on the battlefield and target specific populations with bioweapons. U.S. adversaries may use technologies recklessly to achieve short term gains with no consideration of long range effects.^{6,7}

Accelerated Biomedical Solutions

Viruses and diseases will be highly volatile, mutative, and extremely personalized, potentially challenging an already stressed Army medical response system and its countermeasures. Synthetic biology provides an opportunity for the Army to accelerate the development of treatments and vaccines.

Ensuring land forces are ready to meet future challenges requires optimizing biotechnology and neuroscience advancements. Synthetic biology provides numerous applications that will bridge capability gaps and enable future forces to fight effectively. Future synthetic biology defense applications are numerous and range from sensing capabilities to rapidly developed therapeutics.

The earliest synthetic biology applications in the Future Operational Environment (FOE) could involve infectious diseases. Infectious diseases will continue to impact future operational forces and could quickly render a fighting unit combat ineffective. Currently, disease is treated through a preventative measure (vaccine) or a reactive measure (therapeutic).

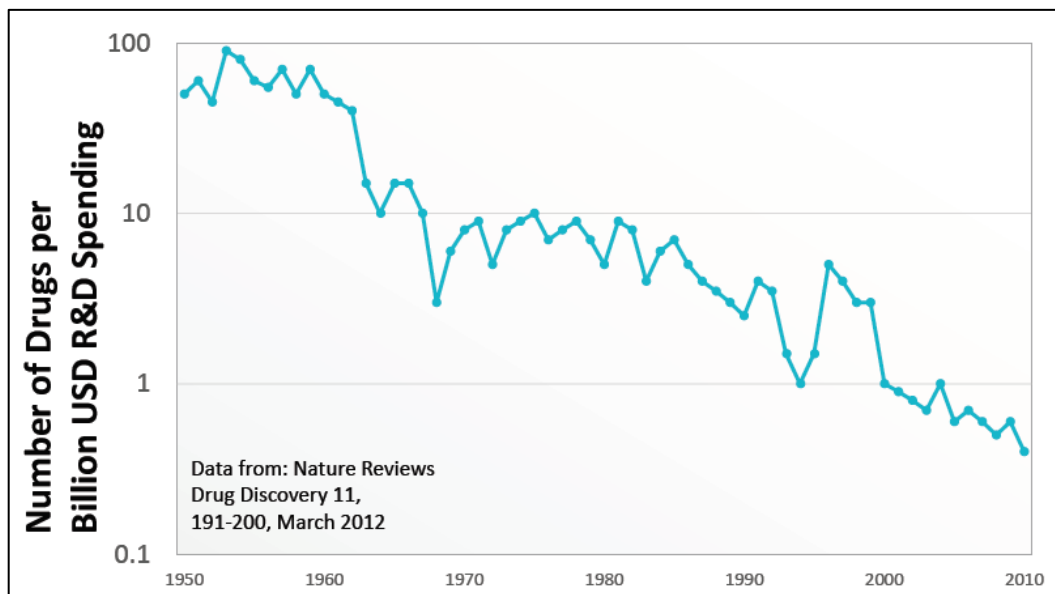
Current vaccine development is challenging, high-risk, and extremely costly. Eroom's law (i.e., drug discovery is becoming slower and more expensive over time despite improvements in technology -- the inverse of Moore's law) will continue to define the future of traditional vaccine development, and drug discovery will remain slow and more expensive over time.⁸ In the near future, lifetime drug sales will be less than the

⁶ <https://www.technologyreview.com/the-download/610034/china-is-already-gene-editing-a-lot-of-humans/>

⁷ <https://www.c4isrnet.com/unmanned/2018/05/07/russia-confirms-its-armed-robot-tank-was-in-syria/>

⁸ Griswold, Kettner, "Engineering Warfighter Resilience Against Biothreats," slide 7, presented at Mad Scientist Bio-Convergence and the Soldier 2050 Conference, 8 March 2018.

cost to bring the respective drugs to market⁹. More alarming is that only a small fraction of diseases are currently curable with medicine¹⁰. Moreover, most vaccines fail in



human clinical trials.^{11,12} Based on these findings, it is evident that a more efficient and effective process is needed to quickly develop treatments, preventatives, and defensives.

In the FOE, the U.S. Army could encounter scenarios similar to the 2013-2016 West African Ebola virus epidemic, which was the most widespread Ebola outbreak in history and triggered the commitment of thousands of U.S. troops. Of even more concern is the future need to deal with mutative and volatile *designer viruses* that target molecular inhibitors and vulnerabilities in traditional treatments. Synthetic biology can be used in a number of ways to revolutionize bio surveillance and the manufacturing and distribution of medical countermeasures (MCMs). The ability to monitor biological threats in real-time, synthesize DNA in the field, and computationally design proteins (with or without known structures) will exponentially improve expeditionary MCM capabilities.

The future Soldier could be equipped with an integrated, networked immune system in order to triage and counter illnesses. The artificial immune system would consist of a wearable platform providing continuous threat monitoring and responsive countermeasure production using DNA sequencing and synthesis to directly program the system to mitigate threats. A forward deployed network of these systems would provide immediate identification and networking communication of potential frontline exposure while also being capable of dynamic updates based on emerging bio threats. By diagnosing Soldiers' illnesses and protecting them from infectious diseases and

⁹ Kovacs, Dr. Gregory, "Managing and Mining Biological Complexity," slide 17, presented at Mad Scientist Bio-Convergence and the Soldier 2050 Conference, 8 March 2018.

¹⁰ Ibid, slide 16

¹¹ <https://www.bio.org/sites/default/files/Clinical%20Development%20Success%20Rates%202006-2015%20-%20BIO,%20Biomedtracker,%20Amplion%202016.pdf>

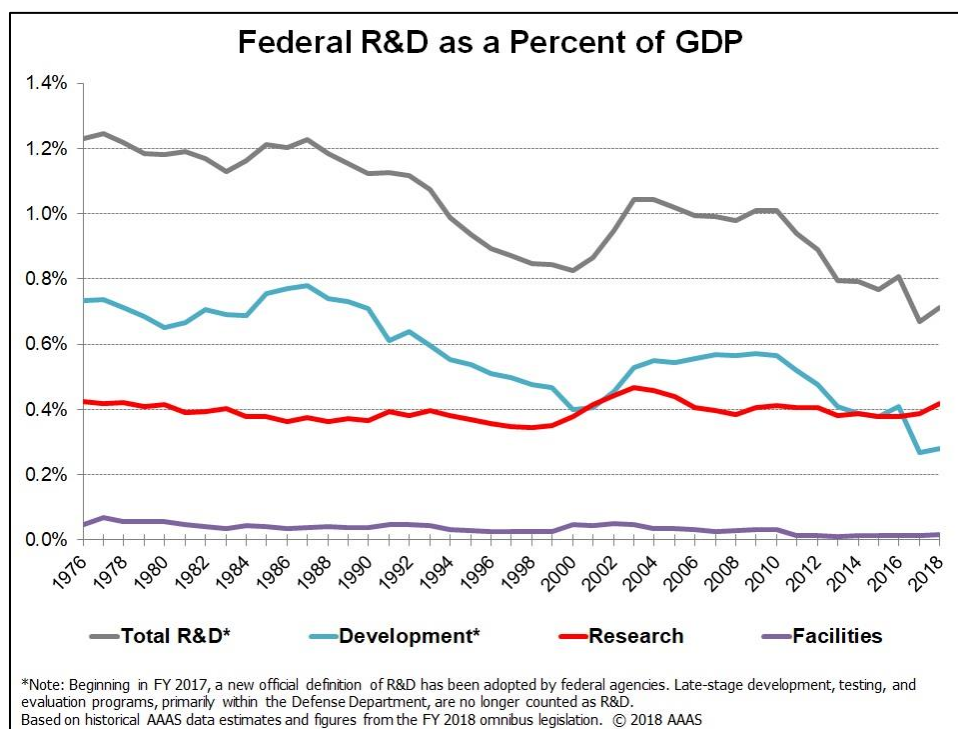
¹² <https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2565686>

chemical and biological threats, future fighting forces will be more agile and lethal in austere environments.

The Changing Innovation Cycle

The dramatic shift in the funding, driving, and demand signals of innovation from the U.S. Government to the commercial sector leads to a critical need for agile prototyping and experimentation in the military, focusing on niche areas of interest to the government.

In the past, government funding has accelerated many technologies that are now not only commonplace, but almost necessary for modern life. Research and Development that led to the creation of GPS, the microchip, the touch screen, and the internet was funded, in-part, by the government¹³. Recent data from the National Institutes of Health (NIH) has shown that there now is an inverse relationship between how novel a concept is and the amount of funding it receives.¹⁴ Not only is this occurrence emerging but there has also been a decrease in government R&D spending as a percentage of GDP. These two trends lead to stifling of Government innovation and exploration of new technologies.



<https://www.aaas.org/page/historical-trends-federal-rd>

¹³ <https://www.newscientist.com/article/mg21929310-200-state-of-innovation-busting-the-private-sector-myth/>

¹⁴ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5062254/>

Private industry and academia have become the driving force behind innovation. While there are some benefits to this – such as shorter development times – there are also risks. For example, investments in industry are mainly driven by market demand which can lead to a lack of investment in areas that are vital to National Defense but have low to no consumer demand. In academia, a majority of graduate students in STEM fields are foreign nationals, comprising over 80% of electrical and petroleum engineering programs.^{15,16} The US will need to find a way to maintain its technological superiority even when most of the expertise eventually leaves the country.

In order to compete with adversaries, government funding of research in academia and increased funding for the more novel, higher risk proposals could prove beneficial. In the private sector, government investment in areas vital to national defense as well as areas of market failure is crucial. A successful example of this cooperation and investment between the government and private industry is Tesla, Inc. The United States Department of Energy loaned \$465 million to Tesla from the 2007 Advanced Technology Vehicles Manufacturing Loan Program¹⁷. Tesla not only innovated a variety of technologies in electric and autonomous automobiles, but also in power generation and storage – areas of military interest. In order to drive innovation, particularly in areas with small markets, like explosive research, or very novel, high risk technologies – the Army can explore these types of investments.

Institutional Challenges in Biotechnology

The advent of new bio-technologies will give rise to moral, regulatory, and legal challenges for the Army of the Future and its business practices, recruiting requirements, Soldier standards, and structure.

The rate of technology development in the synthetic biology field is increasing at a rapid rate. Private individuals or small start-ups with minimal capital can create a new organism for which there is no current countermeasure and the development of one will likely take years¹⁸. This potentiality leads to the dilemma of creating swiftly creating effective policy and regulation that addresses these concerns, but doesn't stifle creativity and productivity in the field for those researching legitimately. Current regulation may not be sufficient, and bureaucratic inflexibility prevents quick reactive and proactive change. Our adversaries may not move so readily to adopt harsher regulations in the bio-technology arena. Rather than focusing on short term solutions, it may be beneficial to take a holistic approach centered in a world where bio-technology is interacting with everyday life¹⁹. The U.S. may have to work from a relative "disadvantage," using safe and legal methods of enhancement while our adversaries may operate below our defined legal threshold.

¹⁵ <https://www.insidehighered.com/quicktakes/2017/10/11/foreign-students-and-graduate-stem-enrollment>

¹⁶ <https://www.nytimes.com/2017/11/03/education/edlife/american-graduate-student-stem.html>

¹⁷ <https://www.energy.gov/lpo/tesla>

¹⁸ Advances in Biotech Security Landscape, Dr. Megan Palmer, YouTube <https://youtu.be/qgkly6jmMVg> accessed 7 June 2018

¹⁹ Ibid

Biological monitoring systems will allow the Army to make decisions about Soldier health and readiness at machine speed. Sensors on the Soldier's body can observe chemical levels, alertness, and susceptibility to disease.²⁰ Such systems would be able to take that information in real-time, process it, and output recommendations based on maximizing effectiveness. This will lessen the burden on commanders who will no longer have to expend resources on maximizing Soldier efficiency and allow them to shift focus to more direct mission-related functions. However, while effective, this would bring about privacy concerns. The Army has never had access to this detailed level of Soldier information in the past.

With the democratization of these new technologies, the Army may have to examine its recruitment process as there may be a larger deviation between the number of enhanced humans and non-enhanced humans. Allowances may have to be created for those who want to join the Military but, due to lack of resources or know how, have only a "natural" body as opposed to those who could afford to artificially or synthetically enhance their strengths or eliminate their weaknesses. The Army may have to further adjust training standards in order to accommodate both groups, whether that means raising them or allowing a different standard for each group. Enhanced Soldiers integrated with machines also raises the opportunity of altering formations. The Army could get more, or the same, lethality from fewer personnel and assets, so units could be smaller without losing effectiveness. The units could be customized and enhancements could be tailored to specific mission sets and geographic areas.

The Ethics of Soldier Enhancement

There are numerous ethical questions that come with the enhancement of Soldiers such as the moral acceptability of the Army making permanent enhancements to Soldiers, the responsibility for returning transitioning Soldiers to a "baseline human," and the general definition of what a "baseline human" is legally defined as.

By altering, enhancing, and augmenting the biology of the human Soldier, the United States Army will potentially enter into uncharted ethical territory. Instead of issuing *items* to Soldiers to complement their physical and cognitive assets, by 2050, the U.S. Army may have the will and the means to issue them increased biological *abilities* in those areas. The future implications and the limits or thresholds for enhancement have not yet been considered. The military is already willing to correct the vision of certain members – laser eye surgery, for example – a practice that could be accurately referred to as human enhancement, so discretely defining where the threshold lies will be important. It is already known that other countries, and possible adversaries, are willing to cross the line where we are not. Russia, most recently, was banned from competition in the 2018 Winter Olympics for widespread performance-enhancing drug violations that were believed to be supported by the Russian

²⁰ Griswold, Kettner, "Engineering Warfighter Resilience Against Biothreats," slide 20, presented at Mad Scientist Bio-Convergence and the Soldier 2050 Conference, 8 March 2018.

Government²¹. Those drugs violate the spirit of competition in the Olympics, but no such spirit exists in warfare.

Another consideration is whether or not the Soldier enhancements are permanent. By enhancing Soldiers' faculties, the Army is, in fact, enhancing their lethality or their ability to defeat the enemy. What happens with these enhancements—whether the Army can or should remove them—when a Soldier leaves the Army is an open question. As stated previously, the Army is willing and able to improve eyesight, but does not revert that eyesight back to its original state after the individual has separated. Some possible moral questions surrounding Soldier enhancement include:

- If the Army were to increase a Soldier's stamina, visual acuity, resistance to disease, and pain tolerance, making them a more lethal warfighter, is it incumbent upon the Army to remove those enhancements?
- If the Soldier later used those enhancements in civilian life for nefarious purposes, would the Army be responsible?

Answers to these legal questions are beyond the scope of this paper, but can be considered now before the advent of these new technologies becomes widespread.

If the Army decides to reverse certain Soldier enhancements, it likely will need to determine the definition of a "baseline human." This would establish norms for features, traits, and abilities that can be permanently enhanced and which must be removed before leaving service. This would undoubtedly involve both legal and moral challenges.

Conclusion

Bio Convergence is incredibly important to the Army of the Future because the future Soldier *is* the Bio. The Warrior of tomorrow's Army will be given more responsibility, will be asked to do more, will be required to be more capable, and will face more challenges and complexities than ever before. These Soldiers must be quickly able to adapt, change, connect and disconnect to a multitude of networks – digital and otherwise – all while carrying out multiple mission-sets in an increasingly disrupted, degraded, and arduous environment marred with distorted reality, information warfare, and attacks of a personalized nature.

Future Soldiers will have the advantage of improving their bodies beyond what is naturally possible to achieve. There will be an increasing amount of investment and research in bio convergence technologies to augment human performance via artificial intelligence (AI), robotics, augmented reality, brain-machine interface, nanotechnology, and synthetic biology capabilities. These advancements have the capacity to greatly

²¹ https://www.washingtonpost.com/sports/russia-banned-from-2018-olympics-following-doping-allegations/2017/12/05/9ab49790-d9d4-11e7-b859-fb0995360725_story.html?noredirect=on&utm_term=.d12db68f42d1

improve the lives and survivability of future Soldiers, but also increase their vulnerability to targeted biological attacks.

Potential improvements to the Soldier include enhanced vision and cognitive abilities, pathogen resistance, and increased strength, speed, agility, and endurance. These new technologies will be accessible to non-state and individual actors and are led by industry and the private sector. The U.S. Armed Forces have the opportunity to invest more in and partner with industry to apply breakthrough technologies to the FOE more quickly and effectively.

One of the major threats to Future armed forces are virulent diseases and the lagging research on vaccines and other medications. The U.S. Army Medical Corps will face a challenge in quarantining, diagnosing, and treating a never before seen disease on the battlefield that has unknown infectious potential. To counteract this threat and surmount such a challenge, the Army has the opportunity to leverage preventative or preemptive synthetic biological modifications to increase resistance and mitigate the risk at a lower cost (both financial and human) than developing a vaccine for an already infected population. Soldiers could have a networked immune system with a wearable component to monitor and triage threats.

The United States Army faces the challenge of keeping pace with a plethora of emerging technologies enabling bio convergence and applying those technologies while maintaining its core values. These technologies may enable its Soldiers to be the highest performing in the world but may also force the Army to grapple with how to recruit, categorize, enhance, and properly transition Soldiers back into the civilian world one day. Some solutions to these challenges will emerge as the technologies themselves are developed, some may be tackled due to emerging crises, and some will take copious amounts of effort and discourse to address. There is a strong likelihood that the future Soldier will be enhanced in innovative and promising ways but will face new biological threat vectors forcing the U.S. Army to face challenges in a very different arena.

Agenda Day 1: Thursday, March 8, 2018

- 0800-0840** Registration
- 0840-0850** **Admin Remarks**, *Mr. Lee Grubbs, Director, Mad Scientist Initiative, G-2, U.S. Army Training and Doctrine Command (TRADOC)*
- 0850-0910** **Welcoming Remarks**, *Dr. William A. Jeffrey, CEO, SRI International*
- Morning Theme: Convergence of Bio with OE Attributes**
- 0910-0930** **Opening Remarks**, *Mr. Peter Kant, Vice President, Federal Partnerships, SRI International*
- 0930-0950** **Opening Remarks**, *Mr. Brynt Parmeter, Civilian Aide to the Secretary of the Army for California (Silicon Valley)*
- 0950-1015** Break
- 1015-1100** **Managing and Mining Complexity in Biology**
Dr. Greg Kovacs, President, SRI Biosciences, SRI International
- 1100-1130** **Human 2.0**
Dr. Amy Kruse, Chief Scientific Officer, The Platypus Institute, Arlington, VA
- 1130-1300** Lunch + Demonstration Site (provided on site)
- Afternoon Theme: Human Enhancement**
- 1300-1330** **Superhuman Intelligence & Human Creativity (Not Live Streamed)**
Dr. Seth Putterman, Professor of Physics and Astronomy, University of California, Los Angeles
- 1330-1400** **Future Fight on the Ground: Why We Need Human Enhancement to Win**
Mr. Andrew Herr, CEO, Helicase
- 1400-1430** **The DNA Utility in Military Environments**
Ms. Stephanie Larson and Ms. Zarah Ahmad, Air Force Research Laboratory (AFRL)
- 1430-1445** Break
- 1445-1515** **Enhanced Reasoning through Targeted Neurostimulation**
Dr. Mike Miller, University of California Santa Barbara, Psychological & Brain Sciences
- 1515-1545** **Engineering Resilience against Bio Weapon Threats**
Mr. Kettner Griswold, Hertz-Draper Research Fellow, George Church Lab & Edward Boyden Lab, Harvard University
- 1545-1615** **Implications of Higher Intelligence for Human Conflict**
Dr. David Brin, Science Fiction Author/Futurist

1615-1630 **Closing Remarks**, *Dr. Philip Perconti, Director, Army Research Laboratory (ARL)*
1700-2000 *No Host Social (directly after conference)*

Agenda Day 2: Friday, March 9 2018

0845-0900 **Welcome Remarks**, *Brigadier General David P. Komar, Director, Capabilities Developments Directorate, Army Capabilities Integration Center*

Day 2 Theme: Democratization of Bio Improvements

0900-0930 **Call for Ideas Winner: The Future ODA 2035-2050**
Mr. Howard Simkin, United States Army Special Operations Command G-9

0930-1000 **Advances in Biotechnology: Evolving the Security Landscape?**
Dr. Megan Palmer, Center for International Security and Cooperation (CISAC), Stanford University

1000-1015 Break

1015-1045 **PLA Human-Machine Integration**
Ms. Elsa Kania, Adjunct Fellow, Center for New American Security (CNAS), Washington, D.C.

1045-1145 **U.S. Army Scientists Panel, the Direction of Technology**
COL Wendy Sammons-Jackson, Ph.D., MEDCOM USAMRMC
Dr. Elizabeth Mezzacappa, RDECOM ARDEC
Dr. Tien Pham, RDECOM ARL

1145-1215 **Warfighter Enhancement (Not Live Streamed)**
Dr. Tim Broderick, Senior Advisor, SRI Biosciences, SRI International

1215-1330 Lunch (provided on site) *Optional Working Lunch - Invitation only*

1330-1400 **Wearables, Big Data, and Health**
Dr. Michael Snyder, Director, Center for Genomics and Personalized Medicine, Stanford University

1400-1430 **Flexible Sensors and Diagnostics: The Revolution in Wearable and Embeddable Technologies**
Mr. Jason Marsh, Director of Technology, NextFlex

1430-1500 **Future Legal and Ethical Implications of Bio Technology**
Mr. Hank Greely, Deane F. and Kate Edelman Johnson Professor of Law and Professor, by courtesy, of Genetics, Stanford University

1500-1530 **Closing Remarks**, *Mr. Thomas Greco, TRADOC DCS, G-2*

Annex 2 – Connect to Mad Scientist

To view the presentations from the Bio-Convergence Conference:

<https://www.youtube.com/playlist?list=PLx2Zn7hPXT7fKwgcty8a6rZgrZCPWG7xV>

To connect with Mad Scientist:

Mad Sci Twitter: @ArmyMadSci

Mad Sci Blog: <http://madsciblog.tradoc.army.mil/>

Mad Sci APAN: <https://community.apan.org/wg/tradoc-g2/mad-scientist>

Mad Sci YouTube: <https://www.youtube.com/user/G2TBOC>

Background

In support of the TRADOC G-2 Mad Scientist initiative, the Office of the Deputy Assistant Secretary of the Army (Research & Technology) and the SciTech Futures Team conducted an online ideation exercise concurrent with Mad Scientist's 8-9 March 2018 conference. The purpose of this exercise was to engage a diverse community of subject matter experts and envision how bio convergence technologies could change the character of future conflict.

While the conference was presented in person at SRI International in Menlo Park, California, the online exercise invited players to contribute their own ideas around the conference's theme of 'Bio-Convergence and Soldier 2050.' This report describes the results of the online exercise.

Game Design

The March 2018 Mad Scientist bio convergence exercise was run using a modified version of the SciTech Futures ideation platform. The exercise design consisted of three interconnecting game components: the **Imaginarium**, **Workshop**, and **Marketplace**.

The **Imaginarium** is designed for quick submission of short "Sparks" around the broader subject of bio convergence and how it will impact the US Army, potential adversaries, and society over the coming decades.

Players could draw inspiration from content in the Imaginarium to submit technology Ideas in the **Workshop**. Workshop submissions reflected specific ideas for future technologies that could emerge over the next 30 years, and players collaborated to improve these ideas.

Ideas that received enough endorsement from the player community were "promoted" into the **Marketplace**, where players could "invest" virtual currency in their favorite ideas. Players were prompted to invest under one of three umbrellas: The US Army, our Adversaries, or Society as a whole.

Top Level Statistics

A total of 25 players contributed 63 Sparks and 49 Ideas during the game. Of the ideas, 46 (94%) received sufficient interest from the player community to move into the

Marketplace for further refinement and assessment. 31 of Marketplace ideas originated as Sparks.

As part of the game, players were able to rate the year by which they thought each idea could become widely available. Most of the ideas were seen as maturing within the next 15-20 years.



Top Players

There are several different metrics that can be used for identifying the top players in a technology foresight game. For this initial analysis we focused on identifying the top players based on the number of ideas contributed to the Workshop and the average investment players made in those ideas. Investment data serves as a useful measure of community endorsement. Presumably, ideas that the crowd likes more should receive more investment. It is important to note that players were allowed to invest in their own ideas. This initial analysis does not separate “self-investment” from the data.

Productivity and investment yielded different player rankings. Based on idea count, the top player was *breakpoint*, with 20 ideas submitted during the game. In contrast, while player *ghorstkj* only submitted one idea, it received the highest investment in the game. The only player to place in the top 5 on both metrics was *k3nsh1n*.

Top players by number of ideas

User name	# of ideas	Avg investment per idea
breakpoint	20	\$6,025
spmorris	6	\$4,083
k3nsh1n	4	\$9,750
vonbig	4	\$8,250
huebschb	3	\$500
khaviland	3	\$333

Top players by investment

User name	# of ideas	Avg investment per idea
ghorstkj	1	\$36,000
bear6	1	\$28,000
datasciburgoon	2	\$16,750
knast	1	\$16,000
k3nsh1n	4	\$9,750

Top Ideas Based On Investment for the Army

Players were asked to invest “on behalf of” three different potential user groups: the U.S. Army, potential future adversaries, and society at large.

The table to the right shows the top 10 ideas based on investment for the Army. Additional detail on several of these ideas is provided on the following pages.

Top 10 Ideas by Investment for U.S Army			
Idea	Created By	\$	Available By
Augmented Reality / Virtual Reality (AR/VR)	ghorstkj	\$27,000	2027
Techno-Human Synthesized Modality	bear6	\$16,000	2048
Adversarial Tattoos Fool AI Vision	datasciburgoon	\$15,500	2033
Enabling culturally appropriate behavior	knast	\$14,500	2028
Wolfpack immunity	breakpoint	\$11,000	2033
Inline Reinterpretation	breakpoint	\$10,500	2033
Empathic record	breakpoint	\$10,500	2033
Computer Assisted Social Interaction Enhancer (CASIE)	vonbig	\$9,500	2040
Neuro co-network	k3nsh1n	\$9,000	2048
Immersive stress inoculation	breakpoint	\$9,000	2042

Top Idea based on investment by the Army - Augmented Reality / Virtual Reality (AR/VR) submitted by user “ghorstkj”

U.S. Army	Adversaries	Society	Available By
\$27,000	\$0	\$7,000	2027

What is it? Commanders and staff are starting to be able to "visualize" the battlefield with increased capabilities from within the Tactical Operations Center (TOC) but most Soldiers on the ground don't have the luxury of "seeing the terrain" until they are actually there. AR/VR on handheld devices are starting to be developed by ESRI and other industry partners. How long will it take to get this capability into the hands of our Soldiers?

Why is it new or different? This is not necessarily new but the difference is trying to invest in some near/mid-term capabilities that will actually assist Soldiers rather than always trying to lean forward to unknown or achievable capabilities that may not even assist Soldiers or their leaders.

Implications - The U.S. Army will continue to dominate in providing Geospatial capabilities for their units but at a much lower level and higher capability. We fool ourselves into thinking that our troops likely to need it the most actually have access to capabilities like this in a deployed or field training environment. We get so used to Google Maps and other commercial capabilities on our personal devices but are severely lacking on government and fielded systems.



Top ideas based on investment for future Adversaries

The table below shows the top 10 ideas based on investment for potential future adversaries. Additional detail on the top idea is provided on the following page.

Top 10 Ideas by Investment for Adversaries			
Idea	Created By	\$	Available By
Prepositioned biological weapons	breakpoint	\$12,000	2035
Adversarial Tattoos Fool AI Vision	datasciburgoon	\$10,500	2033
Supply chain targeted bio espionage systems	vonbig	\$10,000	2036
Techno-Human Synthesized Modality	bear6	\$9,500	2048
Algorithmic Generation of Bio-weapons	spmorris	\$7,500	2038
BCI ransomware	breakpoint	\$5,500	2045
Plague slander	breakpoint	\$5,500	2030
Kudzu infrastructure	breakpoint	\$5,000	2060
Neuro co-network	k3nsh1n	\$3,500	2048
Immersive stress inoculation	breakpoint	\$2,500	2042

Top idea based on investment for future Adversaries - Prepositioned biological weapons submitted by user “breakpoint”

U.S. Army	Adversaries	Society	Available By
\$0	\$12,000	\$0	2035

What is it? (This is presumed to be an adversary system.) Shelf-stable bioprinting systems, combined with basic drones and long-life batteries (e.g., lithium thionyl chloride) and/or energy harvesting techniques, allow the creation and emplacement of prepositioned biological weapons that will not appreciably degrade over a timeframe of 25-50 years.

Why is it new or different? This is a disruptive capability, as it allows the creation of something that normally cannot exist without great difficulty: a prepositioned weapon of mass destruction with credible multi-decade standby endurance.

Implications - A credible "fail-deadly" emplacement-- requiring the receipt of an expected restraint code at regular intervals-- would be a very effective deterrent against most nations. The weapons would be relatively cheap to construct and emplace, and very difficult to detect. The operational requirements are presumed to be a four-man scouting team and a two-man emplacement team. The emplacement time frame is estimated to be two to four weeks. The mission endurance is estimated to be 25-50 years.



Top ideas based on investment for Society

The table below shows the top 10 ideas based on investment for society. These investment reflect players' views on the potential of the technologies to find widespread use outside of a military context.

Additional detail on the top idea is provided on the following page

Top 10 Ideas by Investment for Society			
Idea	Created By	\$	Available By
Augmented Reality / Virtual Reality (AR/VR)	ghorstkj	\$7,000	2027
Super Strength Tattoo Augmentation	Editor	\$4,000	2040
Medevac hibernation	Breakpoint	\$3,500	2035
Symbiotic Blood Filter	Spmorris	\$3,500	2048
GREEN ANTS	Breakpoint	\$3,500	2033
Bio-tech equipment	K3nsh1n	\$3,000	2046
Techno-Human Synthesized Modality	Bear6	\$2,500	2048
Nano potion: Nanorobots to deliver on demand chemicals	K3nsh1n	\$2,500	2043
Quantum Sensors when GPS fails	Jamiepetey	\$2,500	2032
Empathic cartography	Breakpoint	\$2,500	2025

Top ideas based on investment for Society - Augmented Reality / Virtual Reality (AR/VR) submitted by user “ghorstkj”

U.S. Army	Adversaries	Society	Available By
\$27,000	\$0	\$7,000	2027

What is it? Commanders and staff are starting to be able to "visualize" the battlefield with increased capabilities from within the TOC but most Soldiers on the ground don't have the luxury of "seeing the terrain" until they are actually there. AR/VR on handheld devices are starting to be developed by ESRI and other industry partners. How long will it take to get this capability into the hands of our Soldiers?

Why is it new or different? This is not necessarily new but the difference is trying to invest in some near/mid-term capabilities that will actually assist Soldiers rather than always trying to lean forward to unknown or achievable capabilities that may not even assist Soldiers or their leaders.

Implications - The U.S. Army will continue to dominate in providing Geospatial capabilities for their units but at a much lower level and higher capability. We fool ourselves into thinking that our troops likely to need it the most actually have access to capabilities like this in a deployed or field training environment. We get so used to Google Maps and other commercial capabilities on our personal devices but are severely lacking on government and fielded systems.



Conclusion

Within the broader topic of Bio Convergence, we have identified a handful of key trends among user submissions.

Trend 1: Bio Convergence is Accelerating

Bio Convergence has the potential to turn biology problems into software problems. Software moves more quickly than natural selection or any organic system. As humans and technology fuse, the rate of change will increase, setting humanity on a course that could outpace ethical considerations and safety protocols. At the same time, the potential upside in terms of human performance, reduced morbidity, and improved quality of life is tremendous. Bio Convergence will only move faster between now and 2050; the challenge will be society keeping up.

Trend 2: Bio convergence is Democratizing

The tools required to engineer everything from smart sensors to recombinant bacteria are readily available worldwide, leading to a boom in research and development. Experimentation has moved out of government and university labs and into hackerspaces and homes, and are now discussed openly online. Communities have sprung up around artificial intelligence, personalized genomics, and biohacking. Anyone can spend a hundred dollars and the price of a stamp to have their genome sequenced, or a few thousand more to acquire the technology to do it themselves. What they do with that information is now up to them, not any regulatory body or state.

Trend 3: The Risks and Potential of Bio Convergence are huge

Expanding the Bio Convergence community can lead to unparalleled breakthroughs from unexpected sources. From treating disease to enhancing human performance on and off the battlefield, Bio Convergence could literally change all of our lives. Players contributed ideas that drew a hopeful future, improving the survivability of soldiers and helping people live more full lives. They also sketched a bleaker vision of Bio Convergence towards 2050. Biological weapons were once the purview of state actors, many of whom collectively banned their development and production in 1975. This exercise's players see a resurgence of biological weapons, from binary pathogens to hostile biomes.

Trend 4: Bio Convergence is a broad field

From advanced wearables and intelligent tattoos to engineered organs and mind/machine interfaces, Bio Convergence contains a substantial catalogue of potential technologies for soldiers and civilians alike. Players submitted ideas that included dangerous and potentially destabilizing weapons, as well as advances in team collaboration and enhanced empathy. The future of Bio Convergence is uncertain, as

the potential advances are more varied than autonomous vehicles or other unmanned systems, one focus of our prior exercise, as those are existing systems and concepts with a new, AI pilot. Bio Convergence could change the very definition of humanity and intelligence, or it could lead to smarter smart watches.